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HEADQUARTERS QUARTERMASTER RESEARCH & DEVELOPMENT COMMAND

Quartermaster Research & Development Center, US Army

Natick, Massachusetts

(Dr C)

TEXTILE, CLOTHING AND FOOTWEAR DIVISION

Textile Engineering Laboratory Report No. 155

SOME ASPECTS OF THE EVALUATION OF THE USEFUL LIFE
OF NYLON PARACHUTES AND PARACHUTE MATERIALS

by

Louis I. Weiner, Chief

Textile Engineering Laboratory Branch

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of

Project Reference

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SOME ASPECTS OF THE EVALUATION OF THE USEFUL LIFE OF NYLON PARACHUTES AND PARACHUTE MATERIALS

Introduction

Molecular stability is a serious problem facing the producers and users of the new synthetic fibers. Cotton fibers and cotton fabrics have been used for thousands of years and many of the cotton fabrics taken from the tombs of the Pharaohs in Egypt are still serviceable today. Unfortunately, many of the synthetic fibers that have been developed in recent years do not possess the long-term stability of the natural fibers and are subject to deterioration by subtle influences that occur in storage, weathering, exposure to sunlight and atmospheric fumes. Nylon is particularly vulnerable in this respect and has a higher degradation rate from exposure to sunlight than other synthetic fibers. It is also extremely sensitive to acid fumes which are quite prevalent in industrial and semi-industrial areas.

In any planned procurement program for parachute and parachute components serious consideration must be given to the sensitivity of nylon to these deteriorating influences. In addition, studies designed to determine whether parachutes, which have reached the expiration of their stated useful service life, may be used for additional periods of time should include a comprehensive statistical survey of parachutes which have been stored in various locations and used under a variety of conditions to determine whether they still maintain adequate mechanical properties for use. It would be desirable to have a non-destructive test which could be applied to the parachute to determine whether it is still suitable for the intended purpose. Under less ideal conditions, it is possible to spot check the stress-strain characteristics of swatches of fabric cut from parachutes which can then be mended for re-use if found satisfactory. One hundred percent inspection and repair of this type might prove to be feasible for extending the service life of parachutes, particularly those of the cargo type.

Command Program

An aim of the current work* on service life being carried out at the Command is to determine the limits of degradation to be expected which can serve as a basis for determining the extent and severity of the deterioration problem. The approach being followed is to subject parachute components and sub-assemblies to degrading influences such as light, heat and storage under various climatic conditions for periods of time up to and exceeding what might be encountered under the most severe use conditions. From such data, extrapolations may be made to determine the potential

*See Appendix A for the complete Proposed Program of the QM R&D Command on Aerial Supply Equipment. (Applications Engineering Phase only.)

residual service life of existing stocks of parachutes with known use and storage history. With such knowledge, decisions regarding serviceability may be made on a statistical sampling basis rather than 100% inspection. The specific studies which form a part of our current program are outlined in Table 1. While limitations on funds and personnel do not permit a broad frontal attack in all of these areas, studies are in progress on certain phases of some of the tasks listed therein.

Table 1

FACTORS INFLUENCING SERVICE LIFE

1. Solar and ultra-violet radiation;
2. Wetting and drying in sunlight and drying equipment;
3. Permanent set during storage;
4. Mechanical damage in use and maintenance;
5. Durability of seams and thread;
6. Deterioration due to chemical atmospheric agents;
7. Fatigue due to repeated impact loading. (1) ←

A problem that must be considered in evaluating ultimate service life of parachute materials and sub-assemblies is the fact that para-
chute test equipment and conditions of service application which
are not normally used for the evaluation of materials of this type in
the laboratory. For example, stresses are applied to parachute components at speeds exceeding, in many instances, 40 ft. per second and at
local strain rates which may be considerably higher. It is well known
that the mechanical properties of textile materials will vary considerably
depending upon the rate at which load is applied. For example, at low
velocities of application of load, nylon will absorb more strain energy
than silk. However, at high rates of application of load, silk will
absorb twice the energy of nylon. Accordingly, in any study of the
service life, the physical and mechanical properties of interest must be
evaluated at the rates of speed encountered in normal usage of the end
item. At the present time, available equipment permits the evaluation
of small elements of fabric structure such as yarns and possibly seams
at the necessary rates of load. Instrumentation is being developed
which will allow such measurements to be made on all of the textile
components of a parachute and in fact, on complete deployment-bag
static-line assemblies, if necessary.

Unfortunately, all of the work that has been done on the deterioration of nylon to date has been carried out on equipment which evaluates mechanical properties under relatively static conditions. Accordingly, the values obtained are only indicative of the properties of interest in
parachute applications. Another difficulty with the general data that

are available in the textile literature regarding deterioration of nylon arises from the fact that the tests were conducted on structures quite different from those of interest in the parachute field. In fact, some of this information can be misleading, because some types of degradation such as that due to solar radiation occurs at the surface of the material and for thick structures the rate of degradation will be less than normally expected. Parachute materials are quite thin, ranging in weight from 9/10 oz. per sq. yd. to 2 oz. per sq. yd. In such materials, the rate of degradation will be quite rapid because the exposed surface constitutes a considerable amount of the substance of the fabric. In fact, an informal report has been brought to our attention that parachutes from a manufacturer in England sustained 60% failure in use because the manufacturer resorted to drying the parachutes in sunlight after a cleaning operation. Considerations such as the above make it absolutely mandatory that evaluations of properties affecting serviceability be conducted both on the proper materials and under conditions simulating field use.

Solar Radiation

At the present time, several programs are in progress in our laboratory to evaluate the influence of the deteriorating factors which have an influence on service life enumerated in Table 1. The item on solar and ultra-violet radiation is being studied and a series of panels containing the various components of the standard T-10 nylon parachute have been exposed to solar radiation at Fort Lee, Virginia. Complete and detailed records are being made of the energy to which the fabrics and other materials are being exposed and selected exposures are being made under filters to determine what wavelengths produce the most serious degradation. This information may be useful in developing special dyes or finishes to filter out the most degrading types of radiation as a basis for extending the service life of the parachutes. Rates of degradation are being studied both by chemical methods to determine the fundamental molecular changes that occur in the nylon polymer and also by mechanical tests conducted at rates of speed approximating those encountered in normal usage. While we have not obtained sufficient data to allow the presentation of any trends observed at this time, the general nature of the relationships which may be expected are shown in Figure 1, which is based on data obtained from the Harris Handbook of Textile Fibers.

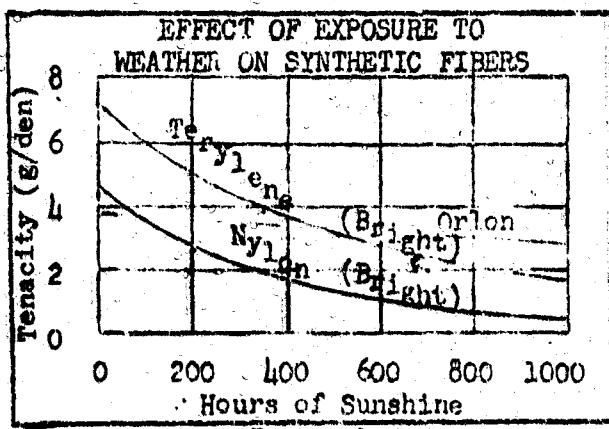


Figure 1

It is apparent from examining the three curves given that the rate of degradation of nylon is quite high, even as evaluated under static conditions. Orlon, on the other hand, according to these data, appears to be rather insensitive to outdoor exposure.

Wetting and Drying

Practically no information is available on the influence of wetting and drying cycles either under conditions of use or in parachute drying equipment on the deterioration rate of nylon. It is well known that nylon is sensitive to heat and it is also known that the tensile properties of nylon are influenced by the presence of moisture; however, the interaction of these two effects, particularly when carried out on a repeated basis such as would occur in the normal use of parachutes, has not been studied. A program has been developed and will be implemented in the very near future to study the effects of cyclic wetting and drying in the new parachute drying equipment that has been developed. In addition to providing basic information on the potential degradation, the experiment is so designed as to assist in establishing optimum operating conditions for the dryer. Standard information released by duPont on the effect of heat on the strength of nylon fabrics is plotted graphically in Figure 2 where it may be seen that both time of exposure and temperature of exposure have a profound influence on the resulting degradation.

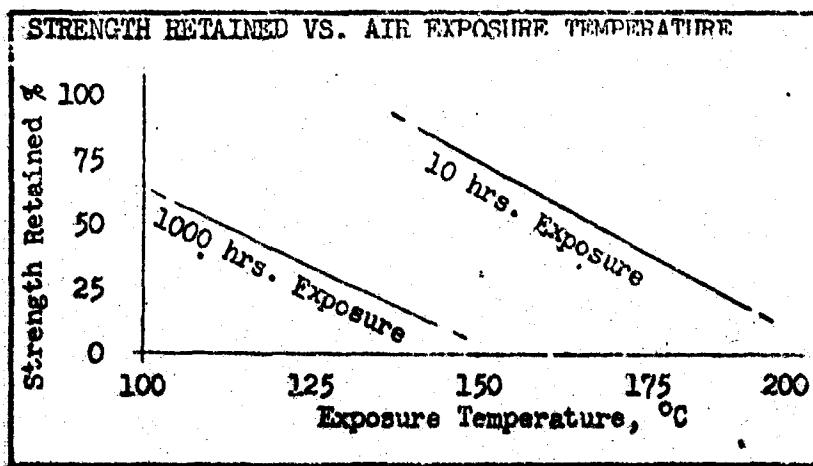


Figure 2

At higher exposure temperatures, degradation will take place in much shorter time intervals. At lower temperatures, equivalent degradation may be obtained only with much longer exposures. The British have also studied this phenomenon both in relation to the exposure temperature for a fixed time interval and the temperature under which the strength of the nylon is tested. The results of their work is shown in Figure 3 in which

temperature of ageing in 16-hour periods is plotted against tenacity for several testing temperatures.

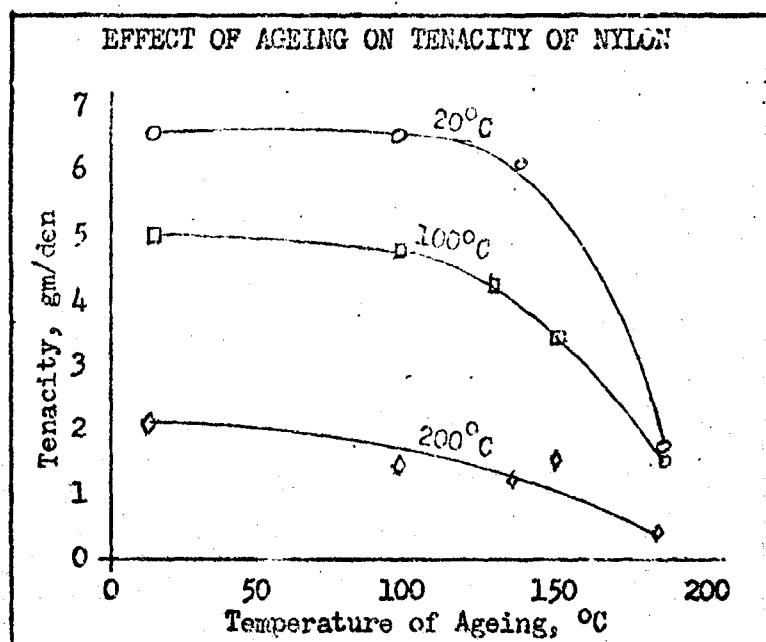


Figure 3

It is apparent from these curves that both the testing and ageing temperatures have a profound influence on the strength of nylon yarn. Our work will extend these findings to include both wetting and drying cycles on parachute materials and under testing conditions that will be more realistic for parachute components.

Storage Problems

Information is becoming available which indicates that a setting process occurs during the storage of nylon which may adversely affect its mechanical properties. The first indication of such storage setting was reported by the Boston Naval Shipyard, where was made the observation that nylon rope that had been in storage for certain lengths of time developed a set which resulted in a marked increase in the stiffness and a resultant loss in utility of the rope. Their investigations indicated that this setting which occurred in storage might be related to the prior heat-treating history of the rope during manufacturing. If such permanent set occurs in nylon parachute fabrics, it is likely that the stress-strain properties, particularly under dynamic conditions, will be adversely affected. In this connection, a controlled storage experiment has been initiated at the Command in which samples of the components of the T-10 parachute have been exposed under simulated storage conditions in climatic chambers which duplicate the diurnal fluctuations in temperature and humidity to be

expected in tropical, desert and summer-temperate climates. Samples will be removed from these three chambers periodically and evaluated, and the results compared with the control test data obtained prior to exposure. In addition, studies are planned on nylon fabrics and parachutes which have been in depot storage in various areas for periods of time up to and including the maximum permissible under regulations at the present time, to determine whether evidence of storage setting exists, and to evaluate its influence on properties related to serviceability.

Mechanical Degradation

Surveys are planned in connection with maintenance studies to determine the most probable cause of damage to parachutes in use and maintenance operations. While such studies have as their major objective the reduction of the need for the great amount of maintenance and repair that is conducted on parachutes and related equipment at the present time, a useful by-product of this work may be the development of means of improving design to reduce or prevent such damage.

Durability of Seams

Another problem that we face in studying the influence of deteriorating mechanisms on the service life of parachutes is the fact that it has been customary to use a finishing agent for parachute fabrics and for thread that may contain acid. This material under certain conditions in use or storage could decompose with the release of acid. At the present time, considerable amount of effort is being given to the development of more stable finishing compounds such as the silicones. It is likely, however, that some of the parachutes in stock have been processed with less stable finishing compounds. A study is planned in which standard finishing compounds that have been used by the parachute industry in the past will be applied to parachute components and subjected to a variety of ageing influences to determine the degree of degradation that can occur. In addition, particular attention in our surveillance analyses will be given to a study of deterioration of thread and seams as a result of possible acid release from such finishing compounds.

Chemical Atmospheric Agents

The increase in acid fumes in industrial and semi-industrial areas has become a problem of major magnitude to many communities. Even in locations far removed from industrial areas "fall-out" during rainfall occurs in which the individual droplets are contaminated with chemical and acidic materials which have a particularly damaging influence on nylon. There are recorded instances in which atmospheric concentration of acid was sufficiently high to cause destruction of nylon hosiery being worn by women. Parachutes have been observed in which

local pitting or hole formation over broad areas has occurred which could possibly have resulted from exposure to contaminated rainfall. Upon evaporation of the water from the drops, concentration of the acid occurs which could easily reach the point causing serious damage. An indication of the loss in strength to be expected from exposure of nylon to acid is given in Table 2. It should be recognized that concentrations of 10% acid may easily develop in localized areas due to evaporation of more dilute solutions.

Table 2

EXPOSURE IN 10% SULFURIC ACID AT 70°F	
<u>Strength Retained %</u>	<u>Nylon 840-140/300</u>
No exposure	100
.1 hrs.	85
1.0 hrs.	76
10.0 hrs.	57
1000.0 hrs.	—

Fatigue Effects

Another area of potential interest is the possibility of materials that have been subjected to continued use over long periods of time. As a result of the repeated stresses to which the nylon is subjected, fatigue effects develop which may considerably reduce the ability of the material to sustain additional impact loadings. While no work is contemplated in this area in the immediate future, it is quite probable that some feasibility studies will be conducted to determine the limits of the deterioration which could possibly occur through this mechanism.

Appendix A

Proposed Program Statement for FY-57 on Aerial Supply Equipment

A. Production and Industrial Engineering Activities on Items Which Have Successfully Completed the Engineering Test Stage Priorities

Not applicable

B. User Testing

Not applicable

C. Technical Advice and Assistance in Non-R&D Areas

(Statements of tasks to be inserted by Command Project Control Office.)

D. Development or Improvement of Special Items or Equipment to Support the QMC Mission and/or Meet Specific Requests from QMC

1. Study of the maintenance and repair of aerial delivery textile items with the objective of reducing the number of repairs necessary, as well as the amount of equipment and personnel required for the work

a. Collection and analysis of data on the types and frequencies of failures occurring in aerial supply textile items, e.g., free-fall bags, parachute and deployment bags

1

b. Development of criteria for the evaluation of the nature and type of failures which result in the need for repairs, as well as of failures which occur in the repaired parts

2

c. The investigation of designs of textile elements such as seams, hems, etc., with a view to making recommendations which will facilitate maintenance and repair by the QMC

1

(1) Study of the effect of needle damage on cargo and personnel parachute canopies and components, deployment bags, and back packs

Priorities

- (2) Study of the strength losses in sewing thread encountered in the various sewing operations caused by needle heat, abrasion by needle and other machine components, and abrasion by the fabric when stitch is being set.
- (3) Determination of the proper relationship of thread size, needle size, finish and type, stitches per inch, stitch type, etc., in order to evolve the optimum stitching requirements for the various textile items used in air supply

2. Evaluation of the effects on the textile components of cargo-type and free-type parachutes, of storage for various repack intervals, for support of a program of the QM Training Command aimed at determining the feasibility of increasing the repack interval, to effect economy in maintenance and man-hours

- a. Study of the textile components of parachutes after various experimental repack intervals as determined by QM Training Command, to determine suitability for continued use
 - (1) Evaluation of physical properties of important textile components
 - (2) Determination of fiber deterioration by chemical tests, and identification of foreign or deleterious material

3. Provision of advice and assistance in the QMC Surveillance Program on textile items and materials used in aerial-supply equipment, with the aim of determining whether savings can be effected by an extension of the present nominal service-life, for the original purpose or for less critical purposes

- a. Evaluation of aerial-supply equipment which has become obsolete in service, with special reference to the aging characteristics of the textile components
 - (1) Physical examination of salvaged Canopy, Cargo Parachute, 25 ft., Rayon

Priorities

b. Examination of textile materials, such as webbing, tape, etc. used in the repair and maintenance of aerial-supply equipment, which have become overage in storage in QM depots

(1) Measurement of impact strength and rupture energy, in comparison with new materials

4. Study of the aging characteristics of textile components in QM air-type equipment with the aim of extending the useful and safe service life of personnel and cargo-type parachutes and/or textile materials used therein

a. Study of the effects of normal dead storage on the physical properties of parachute components in depot stocks under various climatic conditions

(1) Evaluation of the physical properties of canopy fabrics, suspension-line cord, and webbings stored for various periods up to three years in the Cycling Climatic Chambers at moderate-desert, moist-tropical, and summer-temperate conditions

b. Study of the deteriorative effects of solar and ultra-violet radiation on the physical and chemical properties of canopy fabrics, webbing and other textiles used in air-type equipment

(1) Exposure of nylon canopy fabrics, tapes, suspension lines, webbings and threads to natural solar radiation at FEA facilities at Fort Lee, for periods extending from 1 to beyond 28 days; and evaluation of the physical properties of the exposed samples

c. Study of the resistance of threads and seams to aging and exposure under various conditions and cycles, with special reference to oxidative or other forms of degradation induced by lubricating oils used in finishing the fabric or in sewing

(1) Treatment of fabric with various kinds of finishes to be sewed into seams and exposed to various conditions to determine whether the fabric finish has adversely affected thread and seam strength and seam slippage

(2) Treatment of thread with various commercial thread lubricants for exposure to various conditions to determine possible adverse effects on thread and seam durability

Priorities

a. Study of the effects of exposure to various cycles of rain, sunlight, cleaning and drying on the physical properties of textile items 2

5. Study of the mechanical behavior of the textile components of air-type items under simulated dynamic conditions of use

a. Study and comparison of the impact behavior of textile materials in structures in current use, such as Types VIII and XIII webbing, with special reference to the performance of parachute static lines 1
(Massachusetts Institute of Technology)

(1) Development of principles to be utilized in the design of a fabric with improved resistance to impact under high-speed loading

(2) Establishment of a basis for the modification of static lines to improve performance

b. Study and comparison of the impact behavior of various types of seams, stitches, and threads, composed of different man-made fibers, used in parachutes and auxiliary air-type equipment 2
(National Bureau of Standards)

6. Surveillance of the performance of supporting equipment in engineering tests to insure that such performance does not unacceptably alter the properties of the textile components of aerial supply equipment

a. Parachute drying equipment 1
(1) Evaluation of effect on textiles in personnel and cargo parachutes of a variety of types and materials, of drying in newly developed parachute drying equipment to be engineering tested at Fort Lee